Chapter 4: Introduction to GSM

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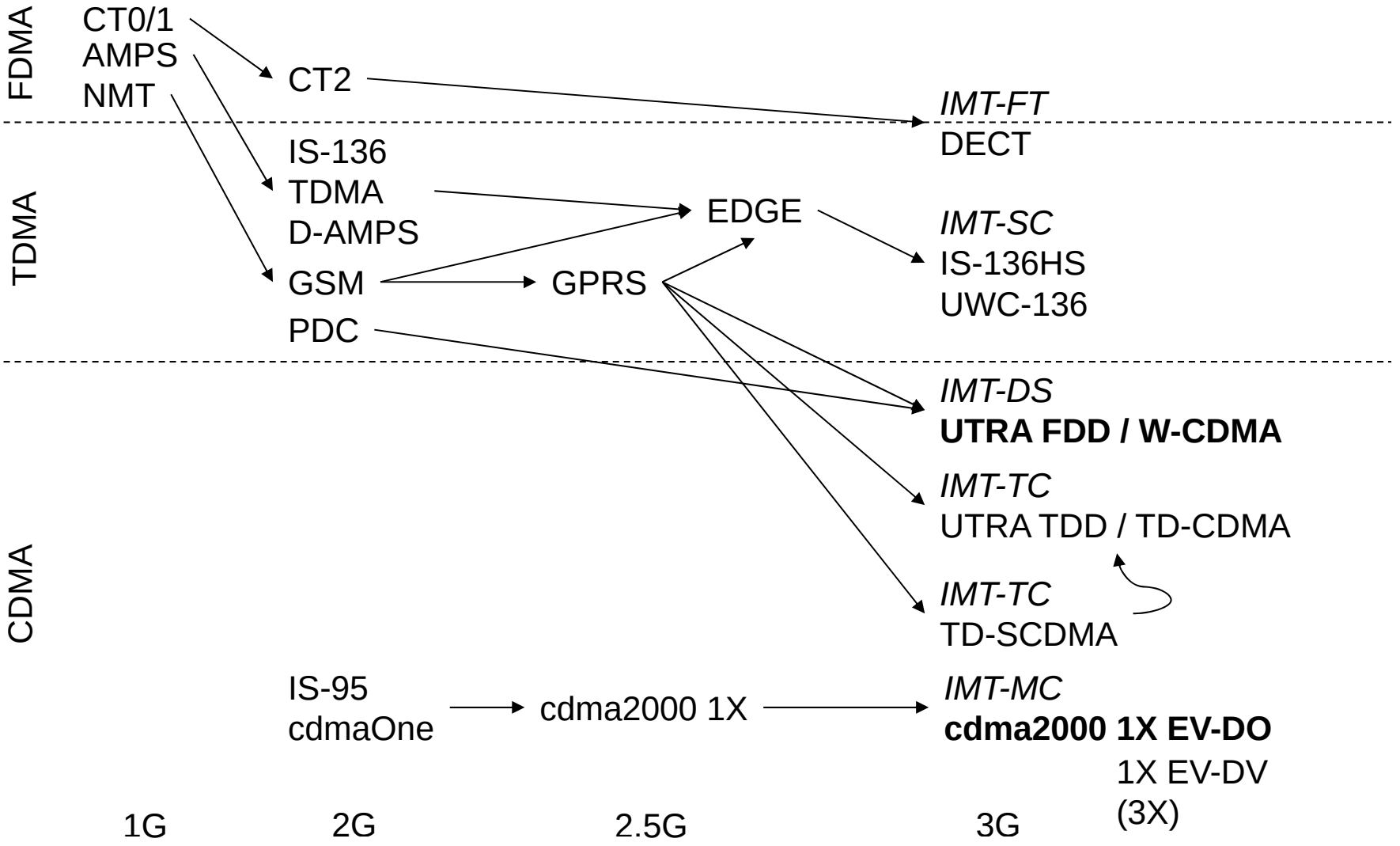
Development of mobile telecommunication systems



GSM: Overview

GSM

- formerly: Groupe Spéciale Mobile (founded 1982)
- now: Global System for Mobile Communication
- Pan-European standard (ETSI, European Telecommunications Standardisation Institute)
- simultaneous introduction of essential services in three phases (1991, 1994, 1996) by the European telecommunication administrations (Germany: D1 and D2)
  ➔ seamless roaming within Europe possible
- today many providers all over the world use GSM (more than 184 countries in Asia, Africa, Europe, Australia, America)
- more than 747 million subscribers
- more than 70% of all digital mobile phones use GSM
- over 10 billion SMS per month in Germany, > 360 billion/year worldwide

Performance characteristics of GSM (wrt. analog sys.)

Communication

- mobile, wireless communication; support for voice and data services

Total mobility

- international access, chip-card enables use of access points of different providers

Worldwide connectivity

- one number, the network handles localization

High capacity

- better frequency efficiency, smaller cells, more customers per cell

High transmission quality

- high audio quality and reliability for wireless, uninterrupted phone calls at higher speeds (e.g., from cars, trains)

Security functions

- access control, authentication via chip-card and PIN

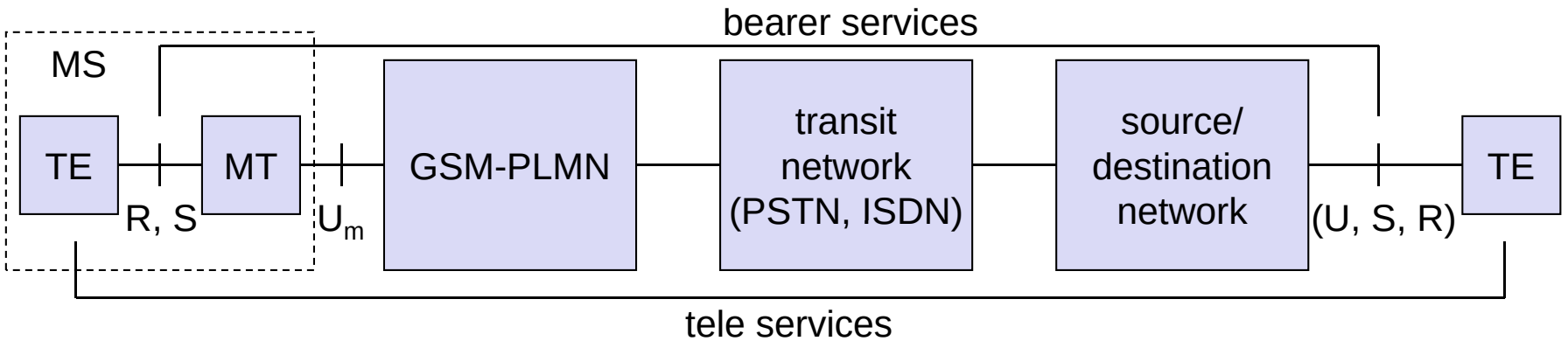
GSM: Mobile Services

GSM offers

- several types of connections
  - voice connections, data connections, short message service
- multi-service options (combination of basic services)

Three service domains

- Bearer Services
- Telematic Services
- Supplementary Services



Bearer Services

- Telecommunication services to transfer data between access points
- Specification of services up to the terminal interface (OSI layers 1-3)
- Different data rates for voice and data (original standard)
  - data service (circuit switched)
    - synchronous: 2.4, 4.8 or 9.6 kbit/s
    - asynchronous: 300 - 1200 bit/s
  - data service (packet switched)
    - synchronous: 2.4, 4.8 or 9.6 kbit/s
    - asynchronous: 300 - 9600 bit/s

Today: data rates of approx. 50 kbit/s possible – will be covered later!

Tele Services I

- Telecommunication services that enable voice communication via mobile phones
- All these basic services have to obey cellular functions, security measurements etc.
- Offered services
  - mobile telephony
    primary goal of GSM was to enable mobile telephony offering the traditional bandwidth of 3.1 kHz
  - Emergency number
    common number throughout Europe (112); mandatory for all service providers; free of charge; connection with the highest priority (preemption of other connections possible)
  - Multinumbering
    several ISDN phone numbers per user possible

Tele Services II

Additional services

- Non-Voice-Teleservices
  - group 3 fax
  - voice mailbox (implemented in the fixed network supporting the mobile terminals)
  - electronic mail (MHS, Message Handling System, implemented in the fixed network)
  - ...

  - Short Message Service (SMS)
    alphanumeric data transmission to/from the mobile terminal using the signaling channel, thus allowing simultaneous use of basic services and SMS

Supplementary services

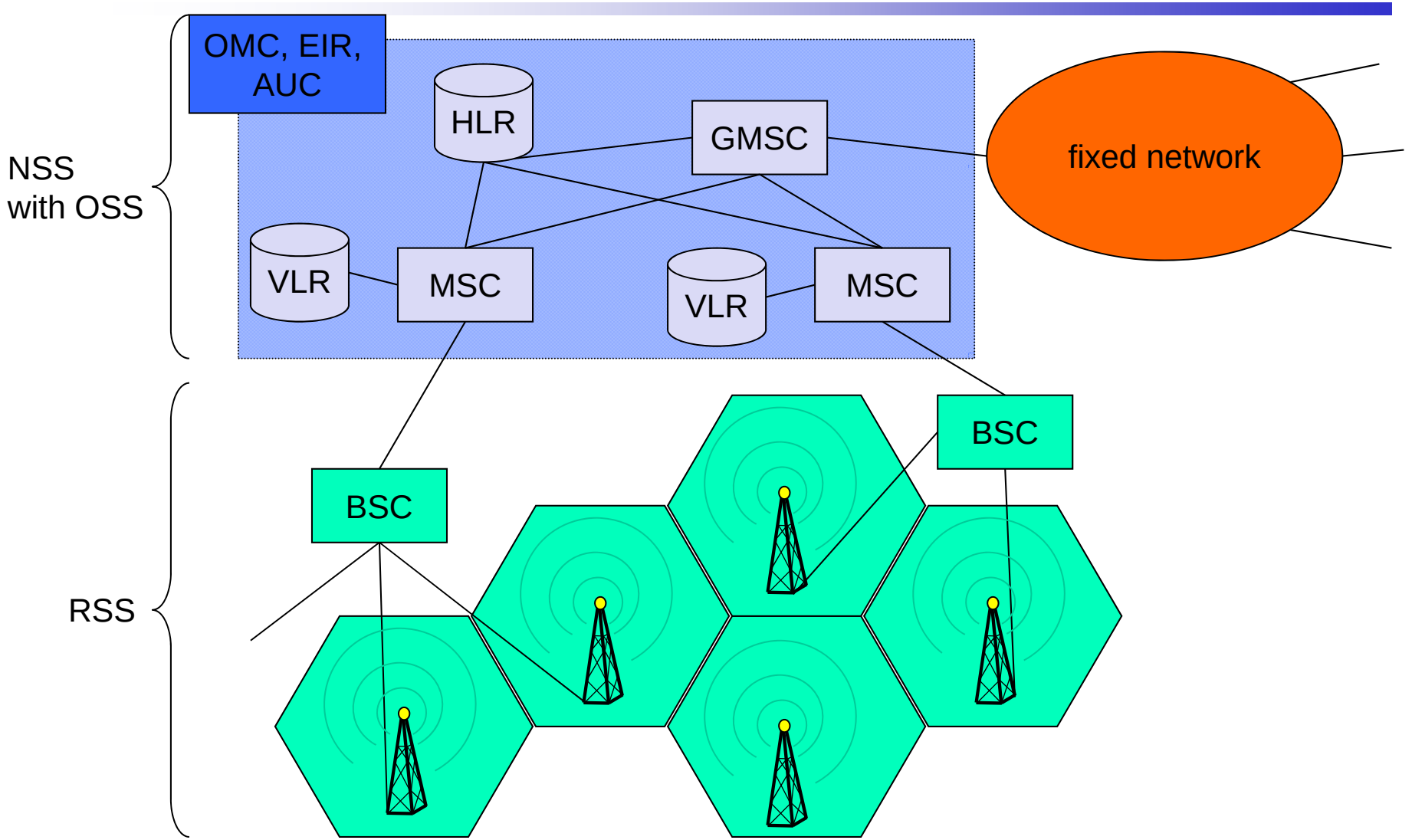
- Services in addition to the basic services, cannot be offered stand-alone
- Similar to ISDN services besides lower bandwidth due to the radio link
- May differ between different service providers, countries and protocol versions
- Important services
  - identification: forwarding of caller number
  - suppression of number forwarding
  - automatic call-back
  - conferencing with up to 7 participants
  - locking of the mobile terminal (incoming or outgoing calls)
  - ...

Architecture of the GSM system

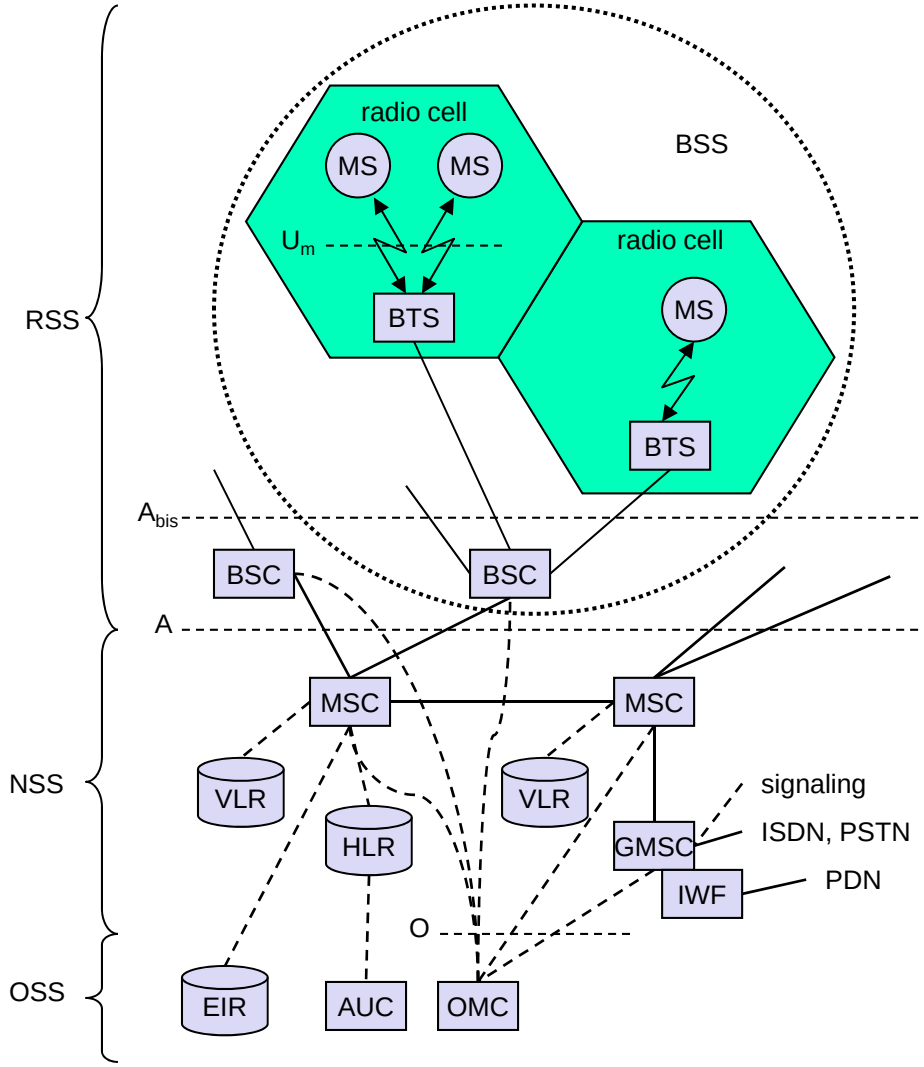
GSM is a PLMN (Public Land Mobile Network)

- several providers setup mobile networks following the GSM standard within each country
- components
  - MS (mobile station)
  - BS (base station)
  - MSC (mobile switching center)
  - LR (location register)
- subsystems
  - RSS (radio subsystem): covers all radio aspects
  - NSS (network and switching subsystem): call forwarding, handover, switching
  - OSS (operation subsystem): management of the network

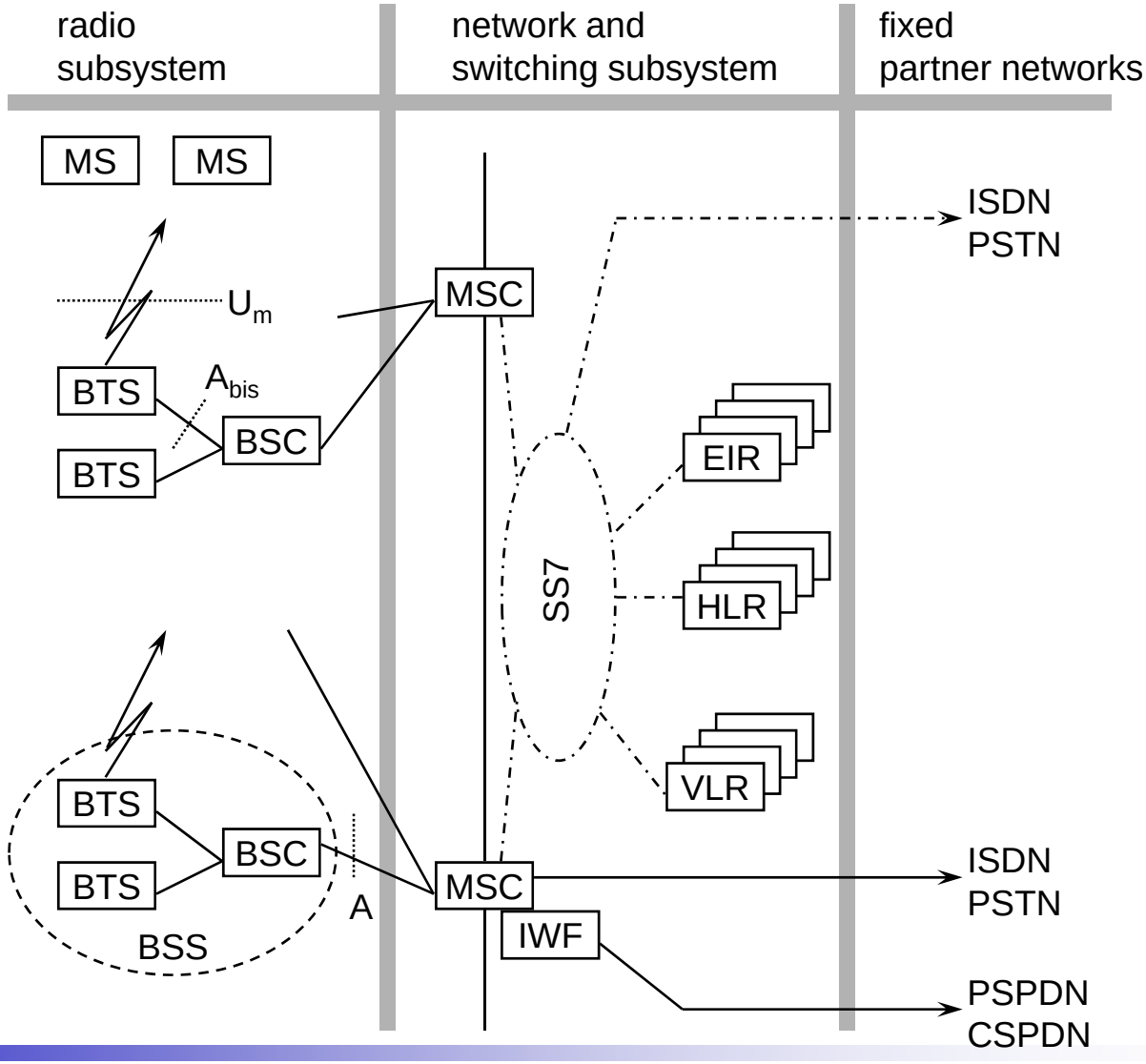
GSM: overview



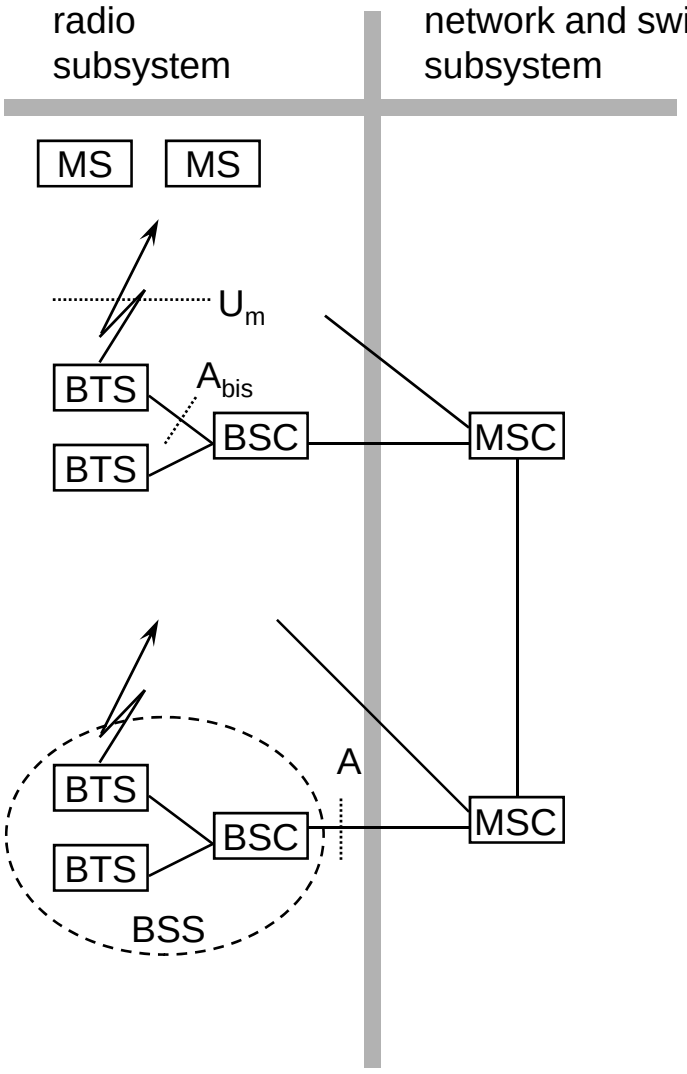
GSM: elements and interfaces



GSM: system architecture



System architecture: radio subsystem



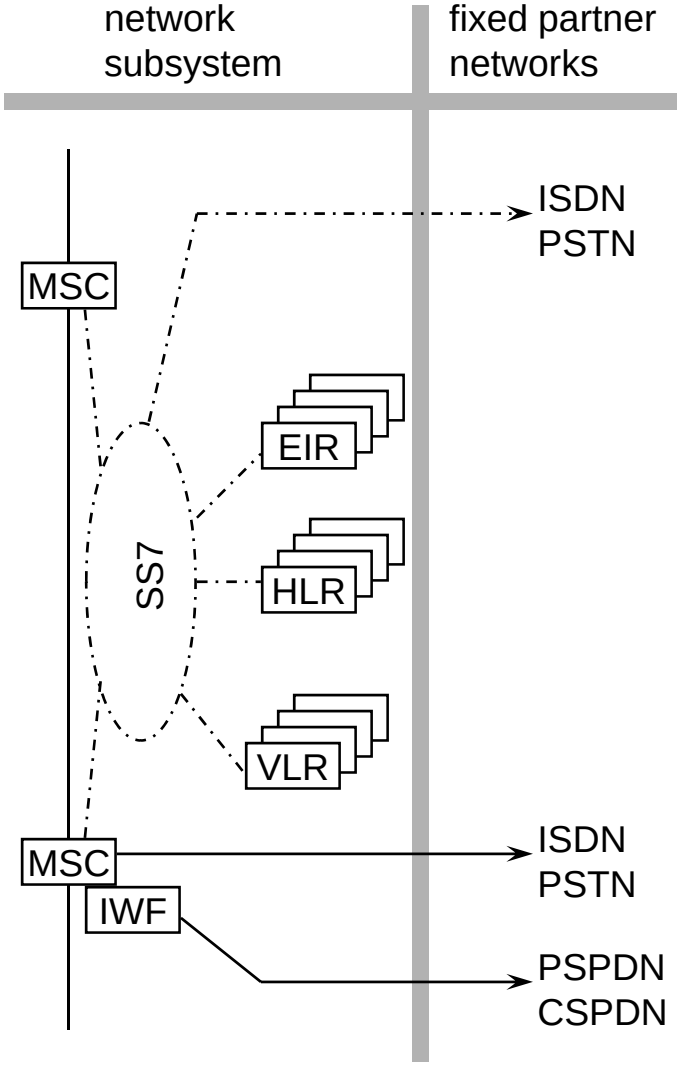
Components

- *MS* (Mobile Station)
- *BSS* (Base Station Subsystem): consisting of
  - *BTS* (Base Transceiver Station): sender and receiver
  - *BSC* (Base Station Controller): controlling several transceivers

Interfaces

- U_m : radio interface
- A_{bis} : standardized, open interface with 16 kbit/s user channels
- *A*: standardized, open interface with 64 kbit/s user channels

System architecture: network and switching subsystem



Components

- *MSC* (Mobile Services Switching Center):
- *IWF* (Interworking Functions)

- *ISDN* (Integrated Services Digital Network)
- *PSTN* (Public Switched Telephone Network)
- *PSPDN* (Packet Switched Public Data Net.)
- *CSPDN* (Circuit Switched Public Data Net.)

Databases

- *HLR* (Home Location *R*egister)
- *VLR* (Visitor Location *R*egister)
- *EIR* (Equipment Identity Register)

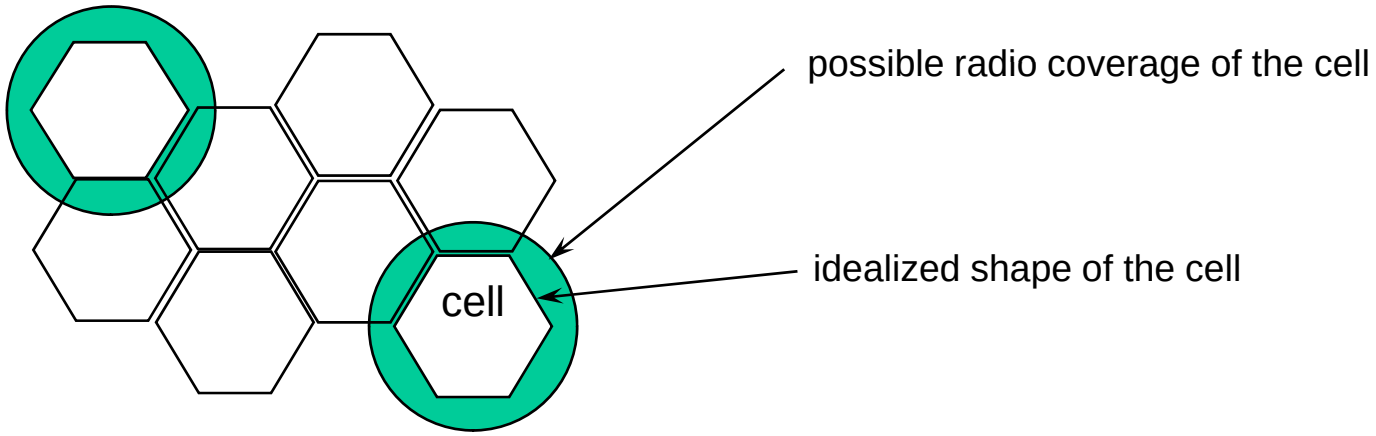
Radio subsystem

The Radio Subsystem (RSS) comprises the cellular mobile network up to the switching centers

- Components
  - Base Station Subsystem (BSS):
    - Base Transceiver Station (BTS): radio components including sender, receiver, antenna - if directed antennas are used one BTS can cover several cells
    - Base Station Controller (BSC): switching between BTSs, controlling BTSs, managing of network resources, mapping of radio channels (U_m) onto terrestrial channels (A interface)
    - BSS = BSC + sum(BTS) + interconnection
  - Mobile Stations (MS)

GSM: cellular network

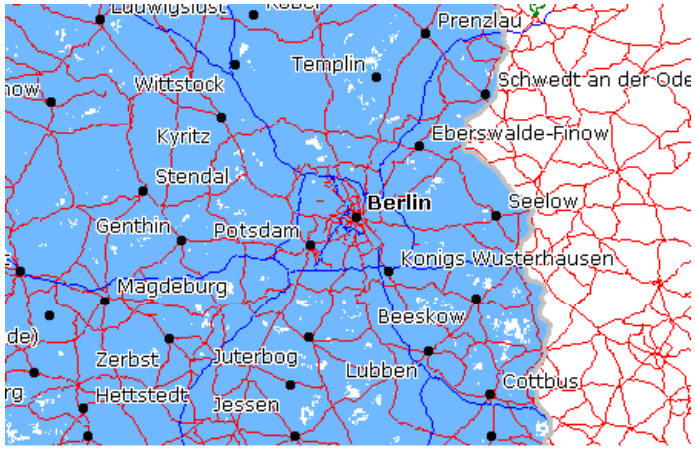
segmentation of the area into cells



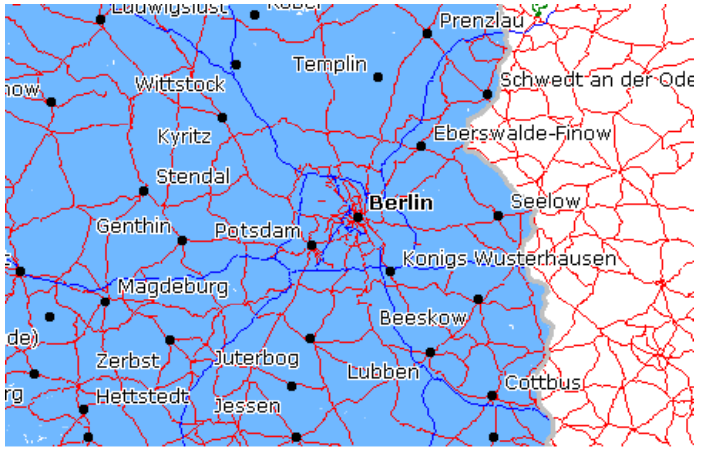
- use of several carrier frequencies
- not the same frequency in adjoining cells
- cell sizes vary from some 100 m up to 35 km depending on user density, geography, transceiver power etc.
- hexagonal shape of cells is idealized (cells overlap, shapes depend on geography)
- if a mobile user changes cells
  handover of the connection to the neighbor cell

Example coverage of GSM networks (www.gsmworld.com)

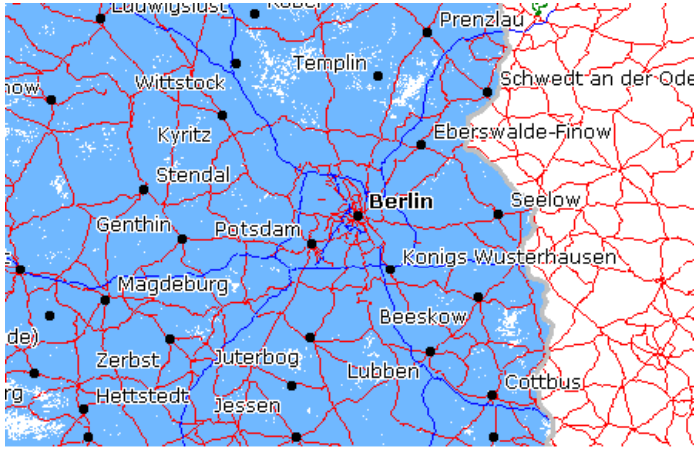
T-Mobile (GSM-900/1800) Berlin



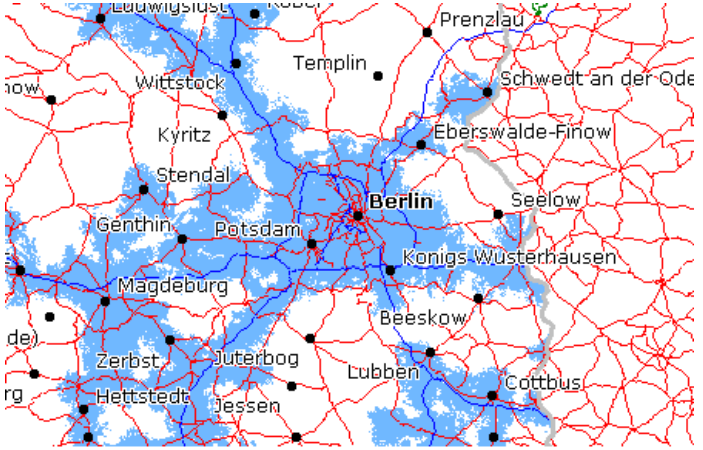
Vodafone (GSM-900/1800)



e-plus (GSM-1800)



O_2 (GSM-1800)



Base Transceiver Station and Base Station Controller

Tasks of a BSS are distributed over BSC and BTS

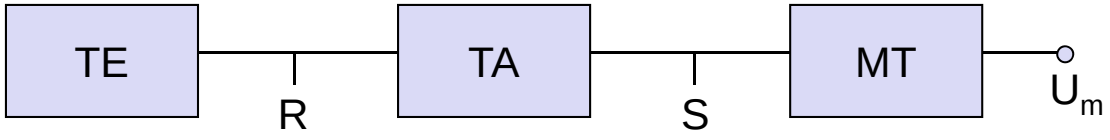
- BTS comprises radio specific functions
- BSC is the switching center for radio channels

Functions	BTS	BSC
Management of radio channels		X
Frequency hopping (FH)	X	X
Management of terrestrial channels		X
Mapping of terrestrial onto radio channels		X
Channel coding and decoding	X	
Rate adaptation	X	
Encryption and decryption	X	X
Paging	X	X
Uplink signal measurements	X	
Traffic measurement		X
Authentication		X
Location registry, location update		X
Handover management		X

Mobile station

Terminal for the use of GSM services

- A mobile station (MS) comprises several functional groups
  - MT (Mobile Terminal):
    - offers common functions used by all services the MS offers
    - corresponds to the network termination (NT) of an ISDN access
    - end-point of the radio interface (U_m)
  - TA (Terminal Adapter):
    - terminal adaptation, hides radio specific characteristics
  - TE (Terminal Equipment):
    - peripheral device of the MS, offers services to a user
    - does not contain GSM specific functions
  - SIM (Subscriber Identity Module):
    - personalization of the mobile terminal, stores user parameters



Network and switching subsystem

NSS is the main component of the public mobile network GSM

- switching, mobility management, interconnection to other networks, system control

- Components
  - Mobile Services Switching Center (MSC)
    controls all connections via a separated network to/from a mobile terminal within the domain of the MSC - several BSC can belong to a MSC
  - Databases (important: scalability, high capacity, low delay)
    - Home Location Register (HLR)
      central master database containing user data, permanent and semi-permanent data of all subscribers assigned to the HLR (one provider can have several HLRs)
    - Visitor Location Register (VLR)
      local database for a subset of user data, including data about all user currently in the domain of the VLR

Mobile Services Switching Center

The MSC (mobile switching center) plays a central role in GSM

- switching functions
- additional functions for mobility support
- management of network resources
- interworking functions via Gateway MSC (GMSC)
- integration of several databases

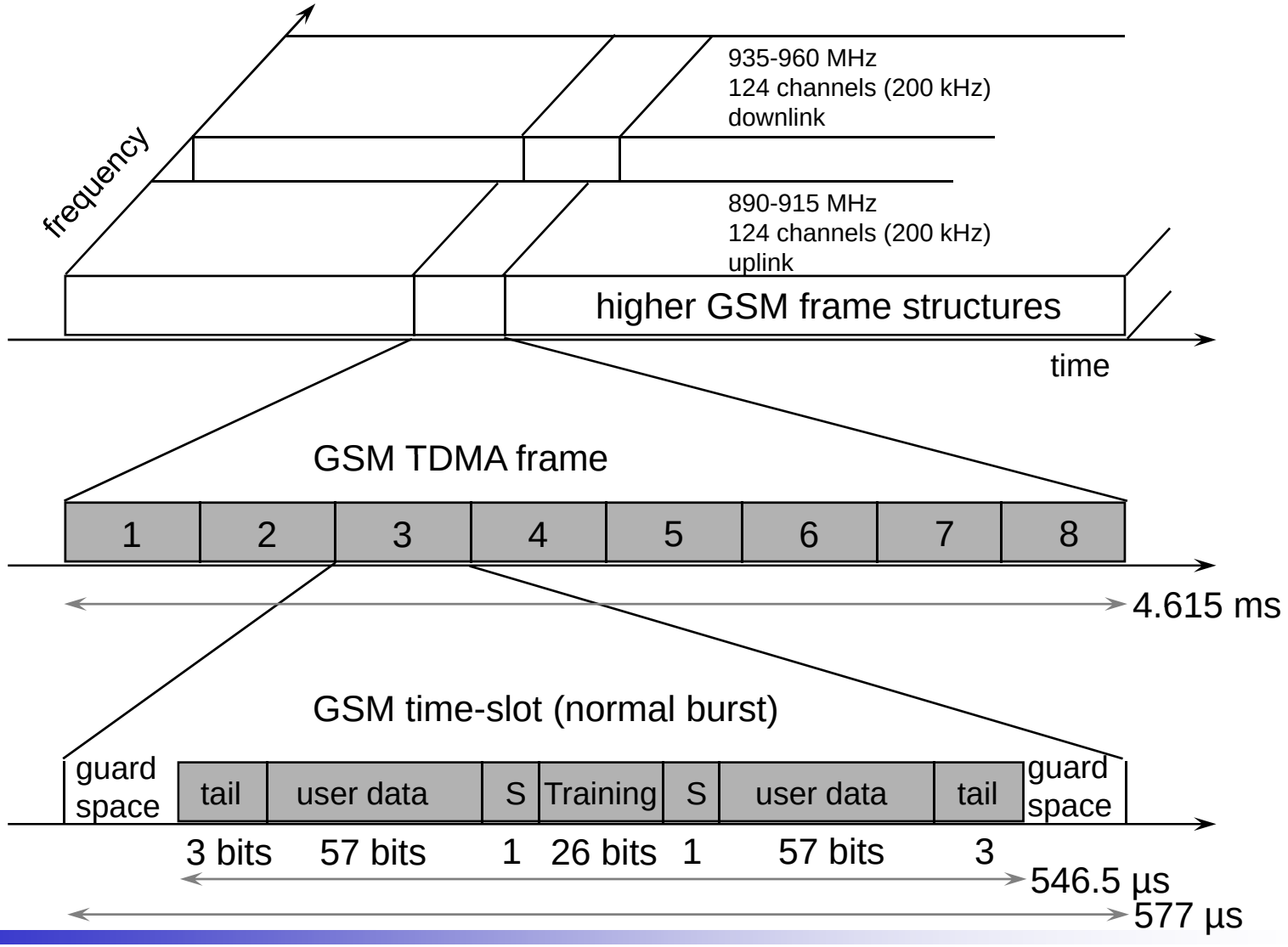
- Functions of a MSC
  - specific functions for paging and call forwarding
  - termination of SS7 (signaling system no. 7)
  - mobility specific signaling
  - location registration and forwarding of location information
  - provision of new services (fax, data calls)
  - support of short message service (SMS)
  - generation and forwarding of accounting and billing information

Operation subsystem

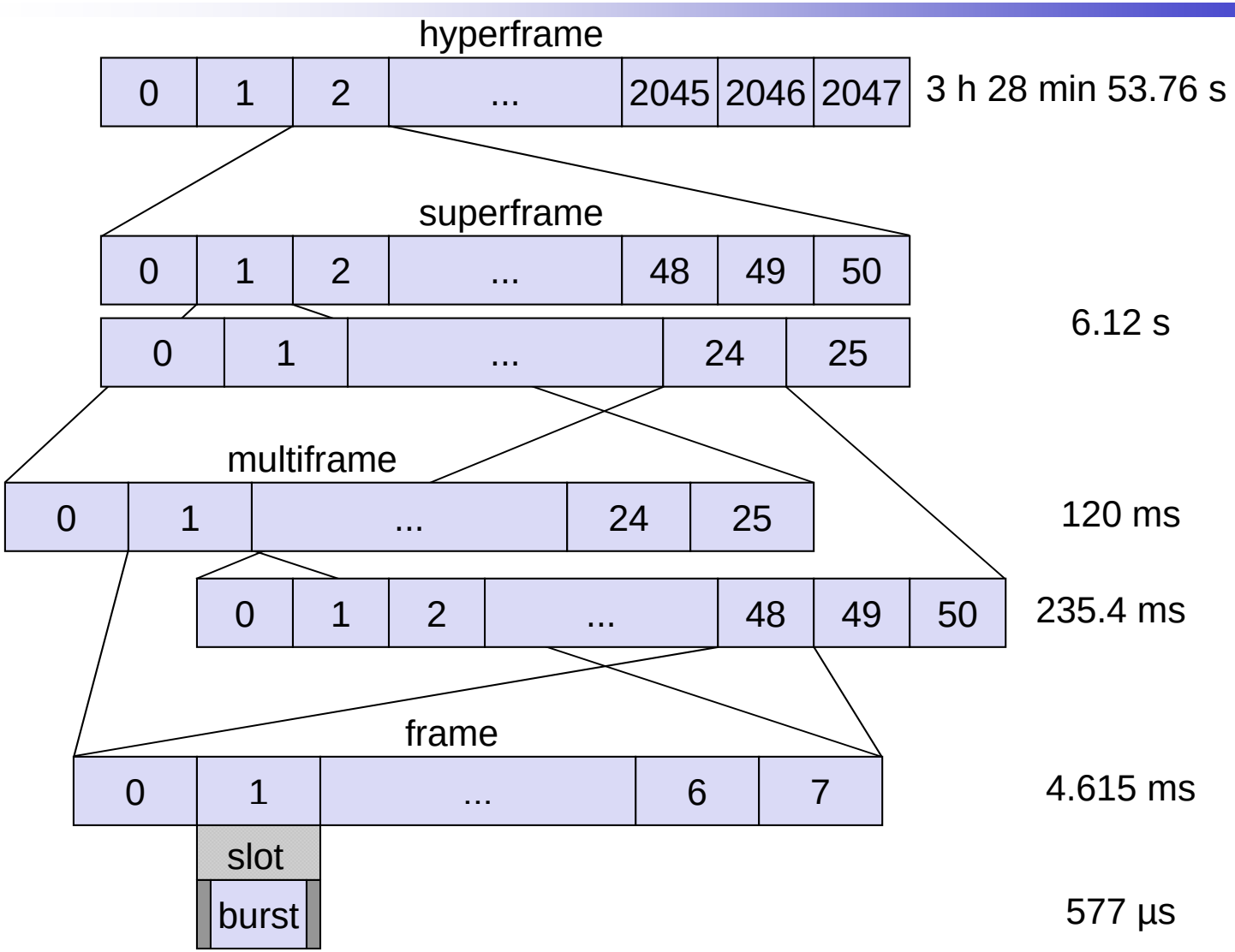
The OSS (Operation Subsystem) enables centralized operation, management, and maintenance of all GSM subsystems

- Components
  - Authentication Center (AUC)
    - generates user specific authentication parameters on request of a VLR
    - authentication parameters used for authentication of mobile terminals and encryption of user data on the air interface within the GSM system
  - Equipment Identity Register (EIR)
    - registers GSM mobile stations and user rights
    - stolen or malfunctioning mobile stations can be locked and sometimes even localized
  - Operation and Maintenance Center (OMC)
    - different control capabilities for the radio subsystem and the network subsystem

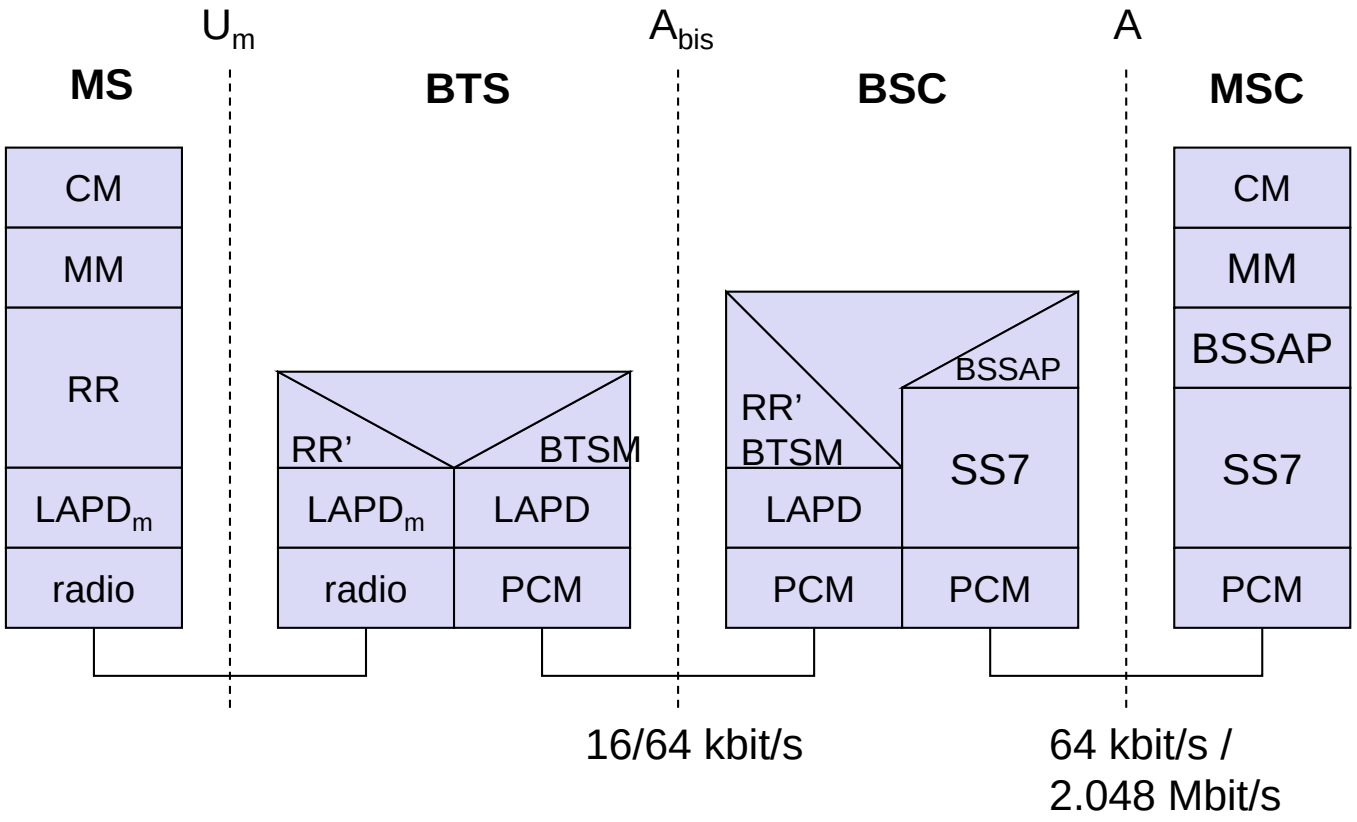
GSM - TDMA/FDMA



GSM hierarchy of frames

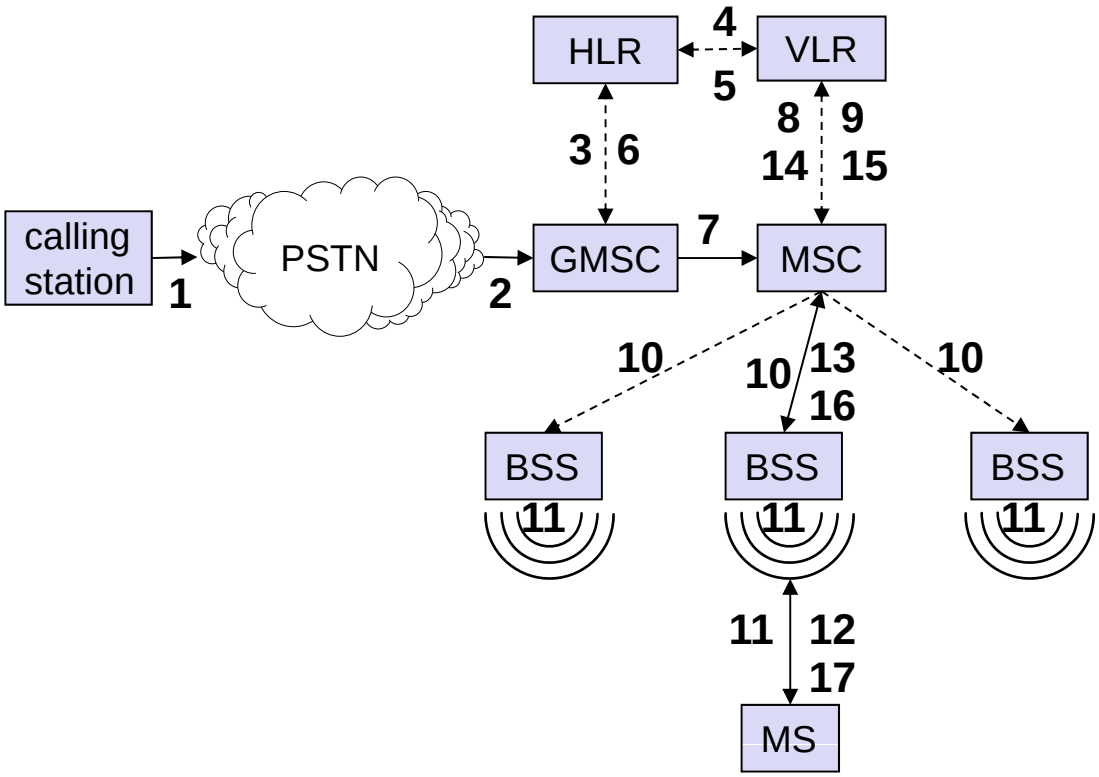


GSM protocol layers for signaling



Mobile Terminated Call

1: calling a GSM subscriber
2: forwarding call to GMSC
3: signal call setup to HLR
4, 5: request MSRN from VLR
6: forward responsible MSC to GMSC
7: forward call to current MSC
8, 9: get current status of MS
10, 11: paging of MS
12, 13: MS answers
14, 15: security checks
16, 17: set up connection



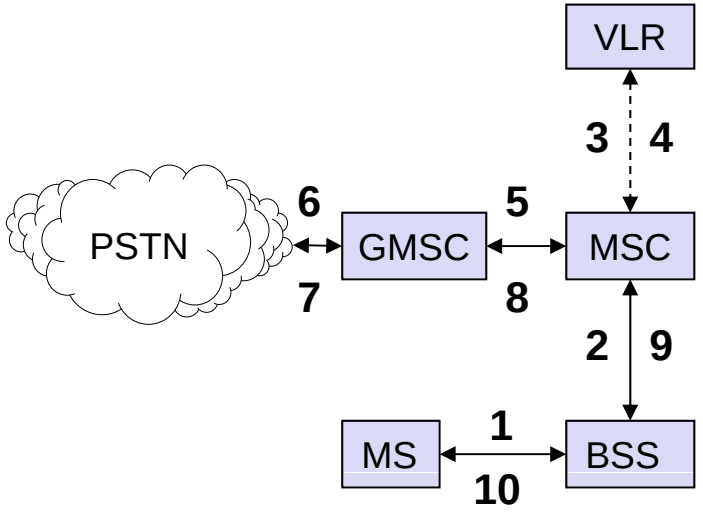
Mobile Originated Call

1, 2: connection request

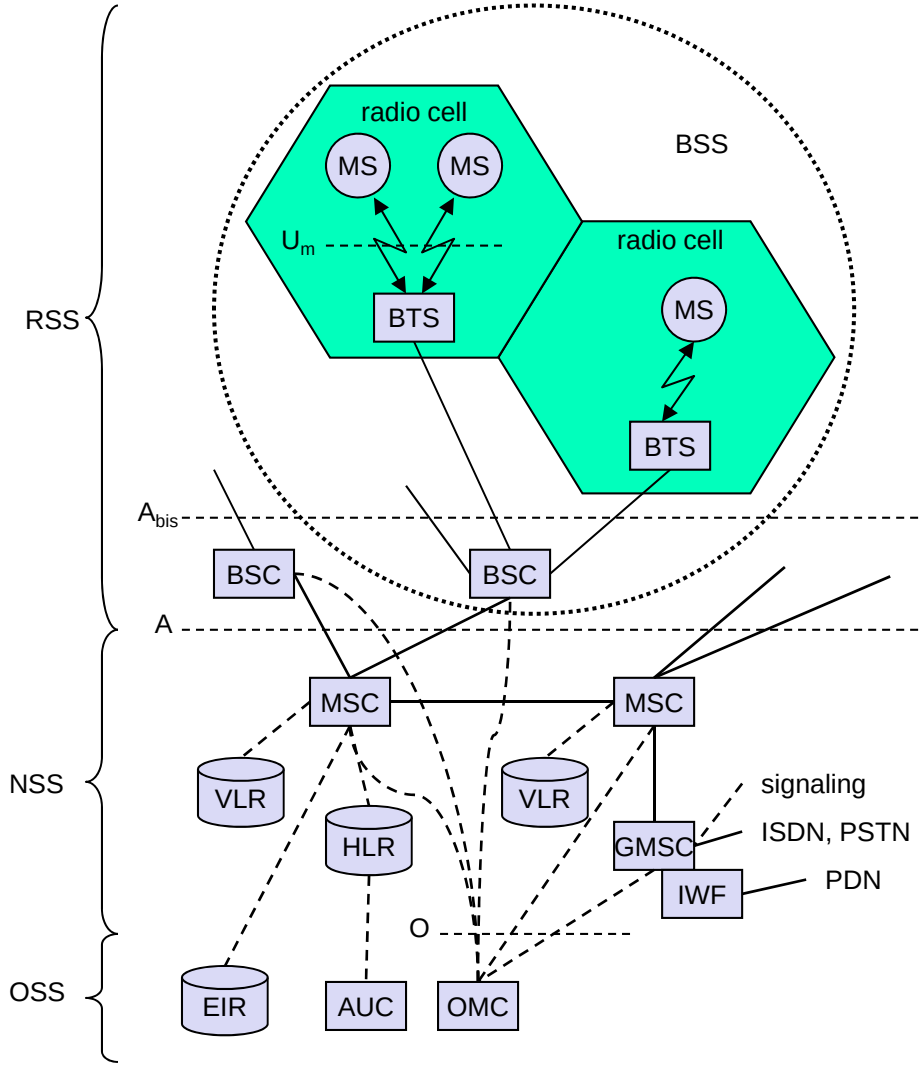
3, 4: security check

5-8: check resources (free circuit)

9-10: set up call



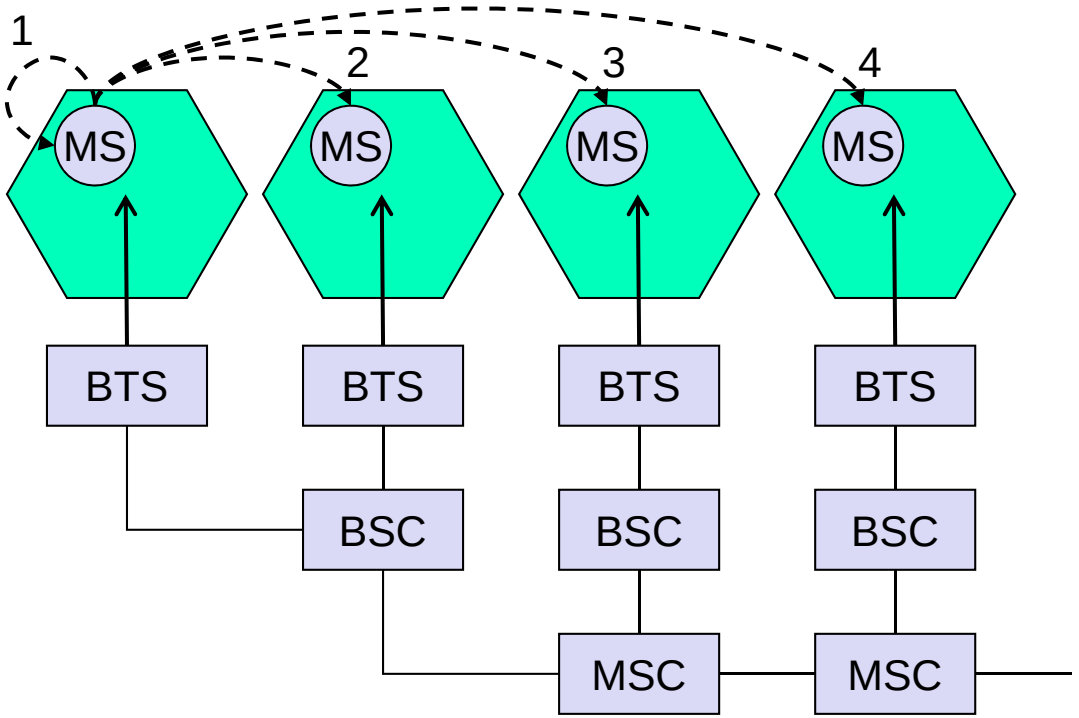
GSM: elements and interfaces



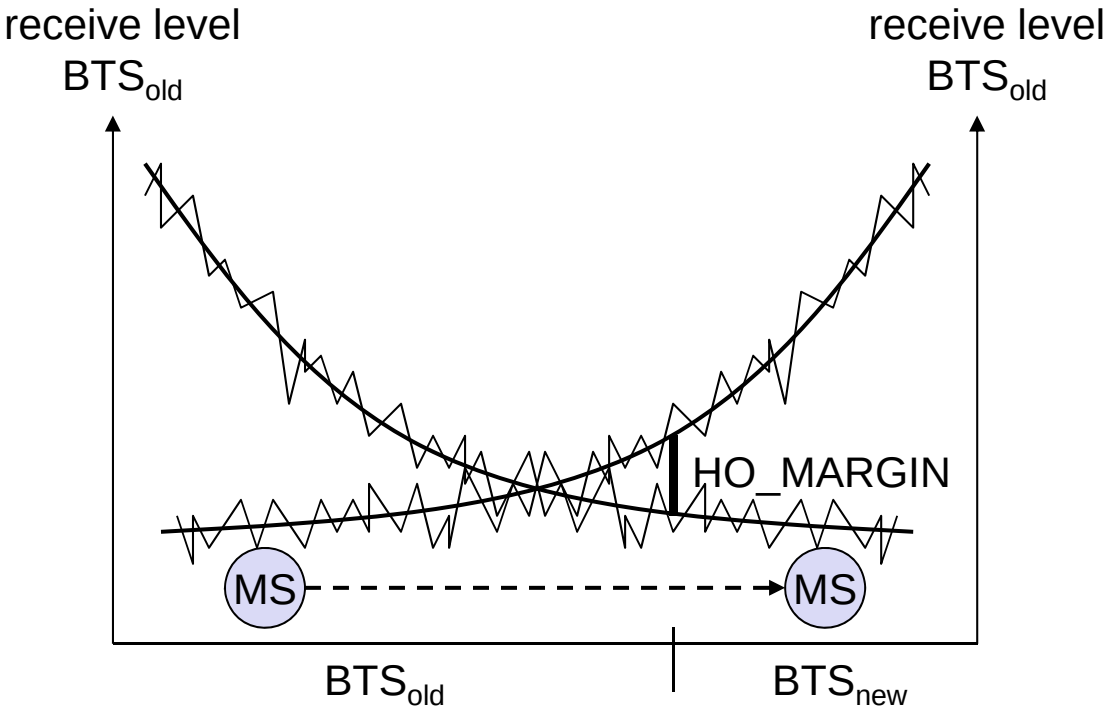
Handover (Handoff)

Handover	Description
Intra-cell / Intra-BTS	The channel for the connection is changed within the cell, e.g., if the channel has a high level of interference. The change can apply to another frequency of the same cell or to another time slot of the same frequency.
Inter-cell / Intra-BSC	In this case there is a change in radio channel between two cells that are served by the same BSC.
Inter-BSC / Intra-MSC	A connection is changed between two cells that are served by different BSCs but operate in the area of the same MSC.
Inter-MSC	A connection is changed between two cells that are in different MSC areas.

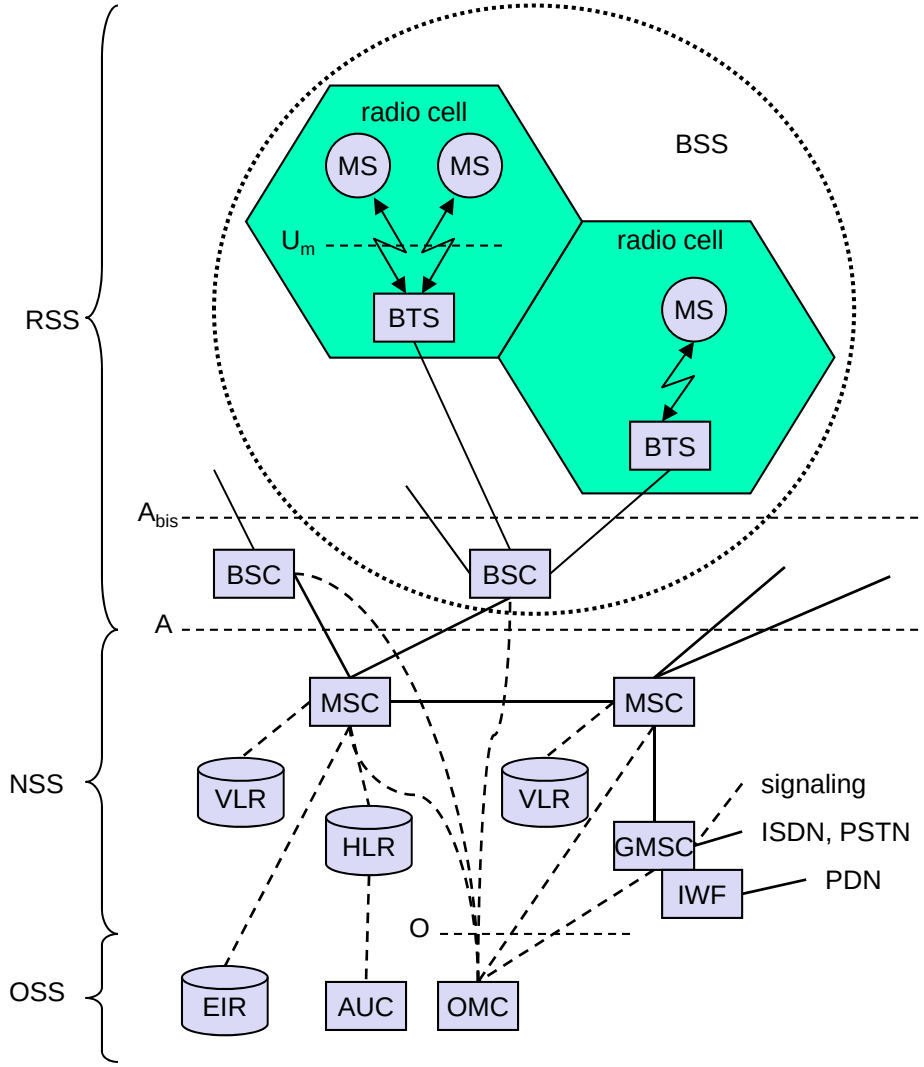
4 types of handover



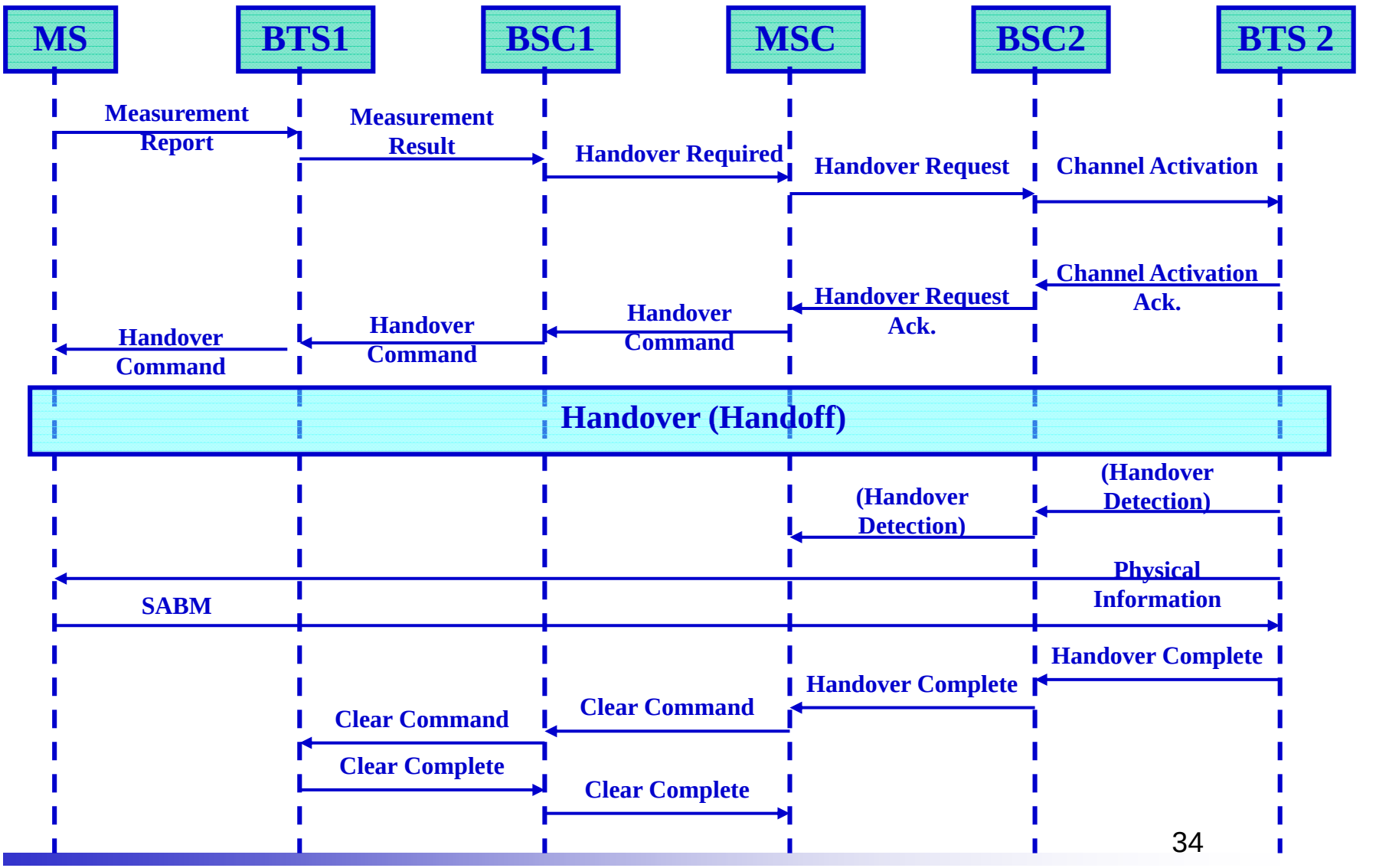
Handover decision



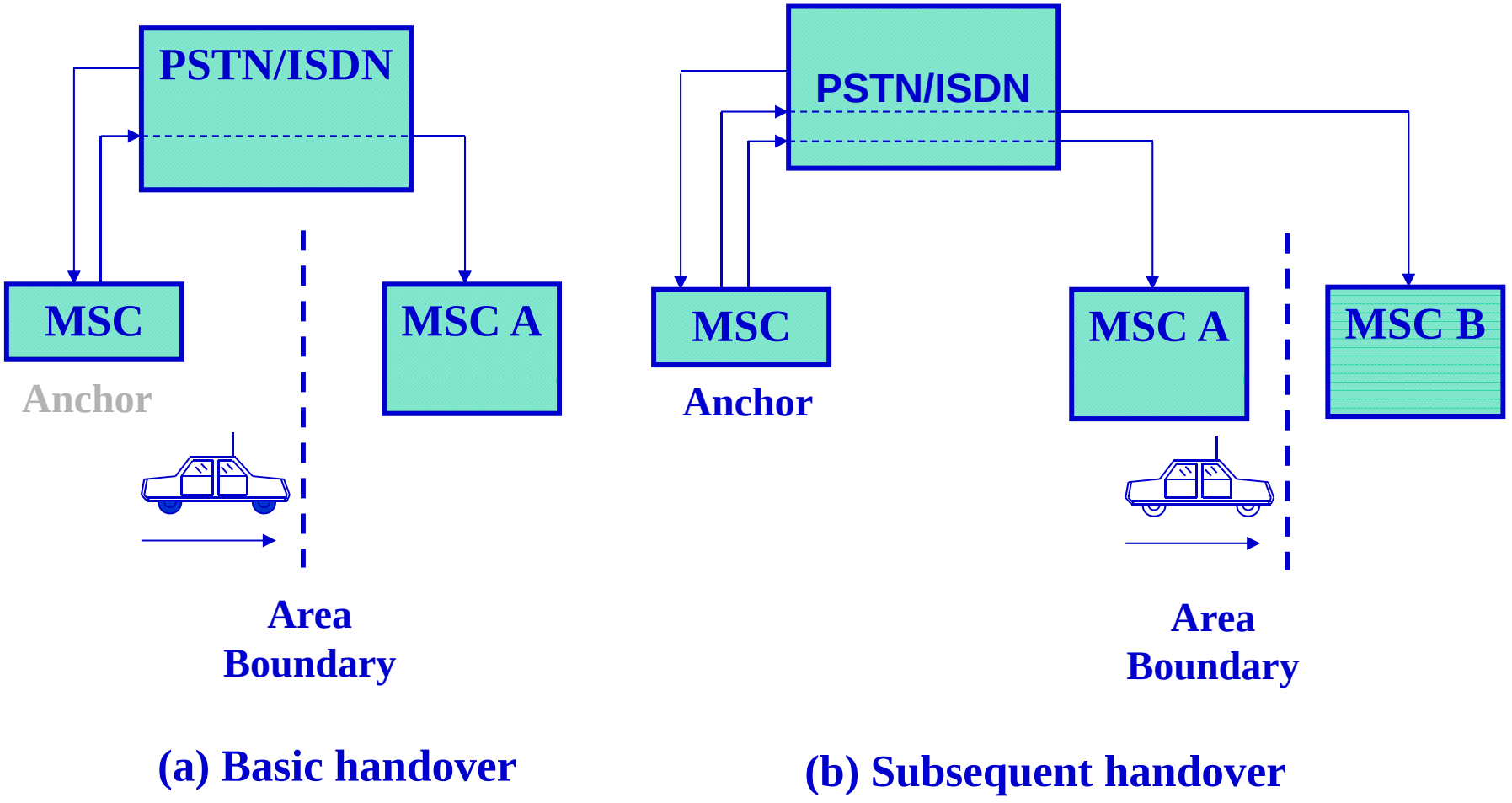
GSM: elements and interfaces



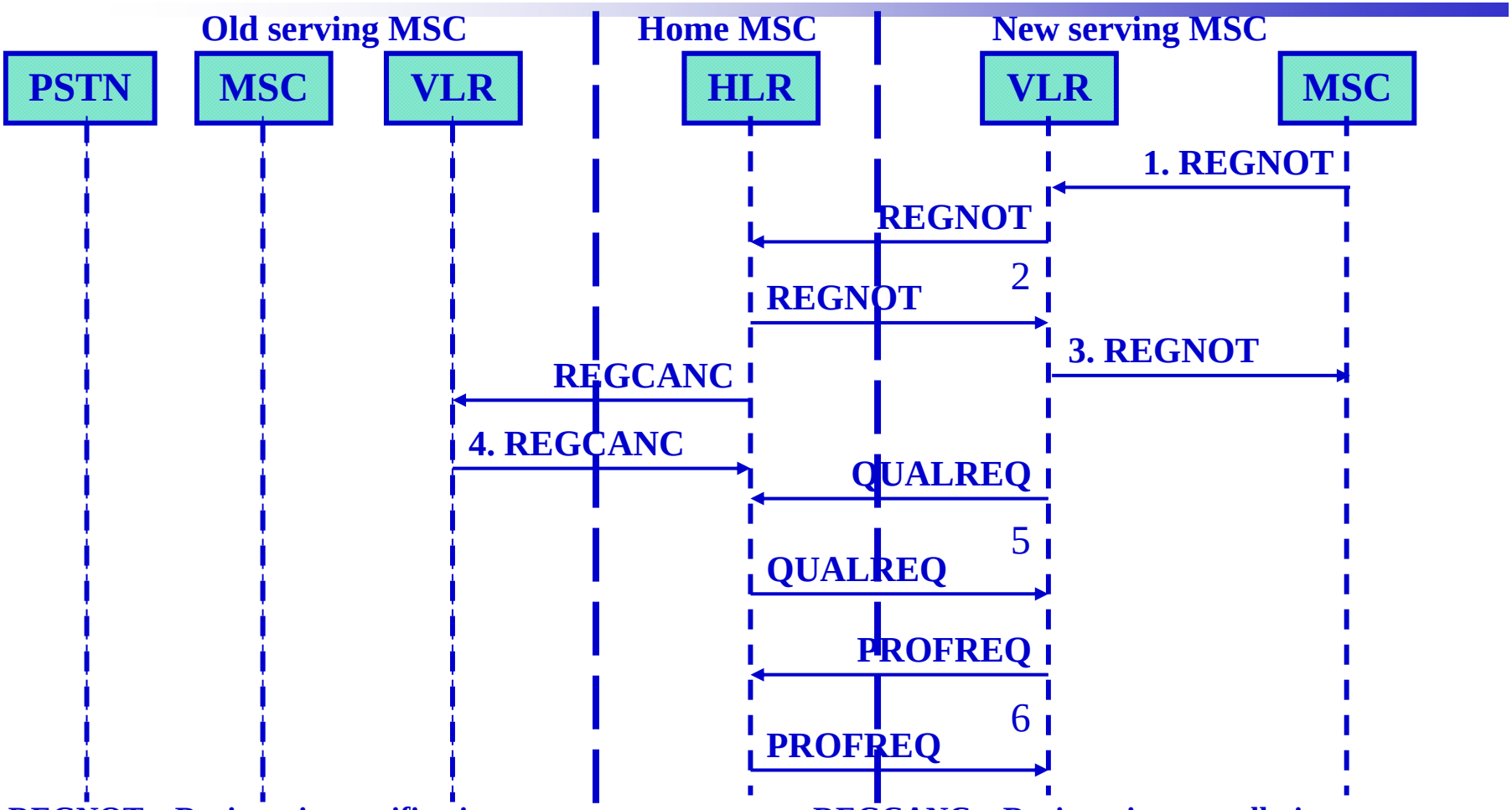
Intra-MSC Handover



Inter-MSC Handover



Registration with a New MSC



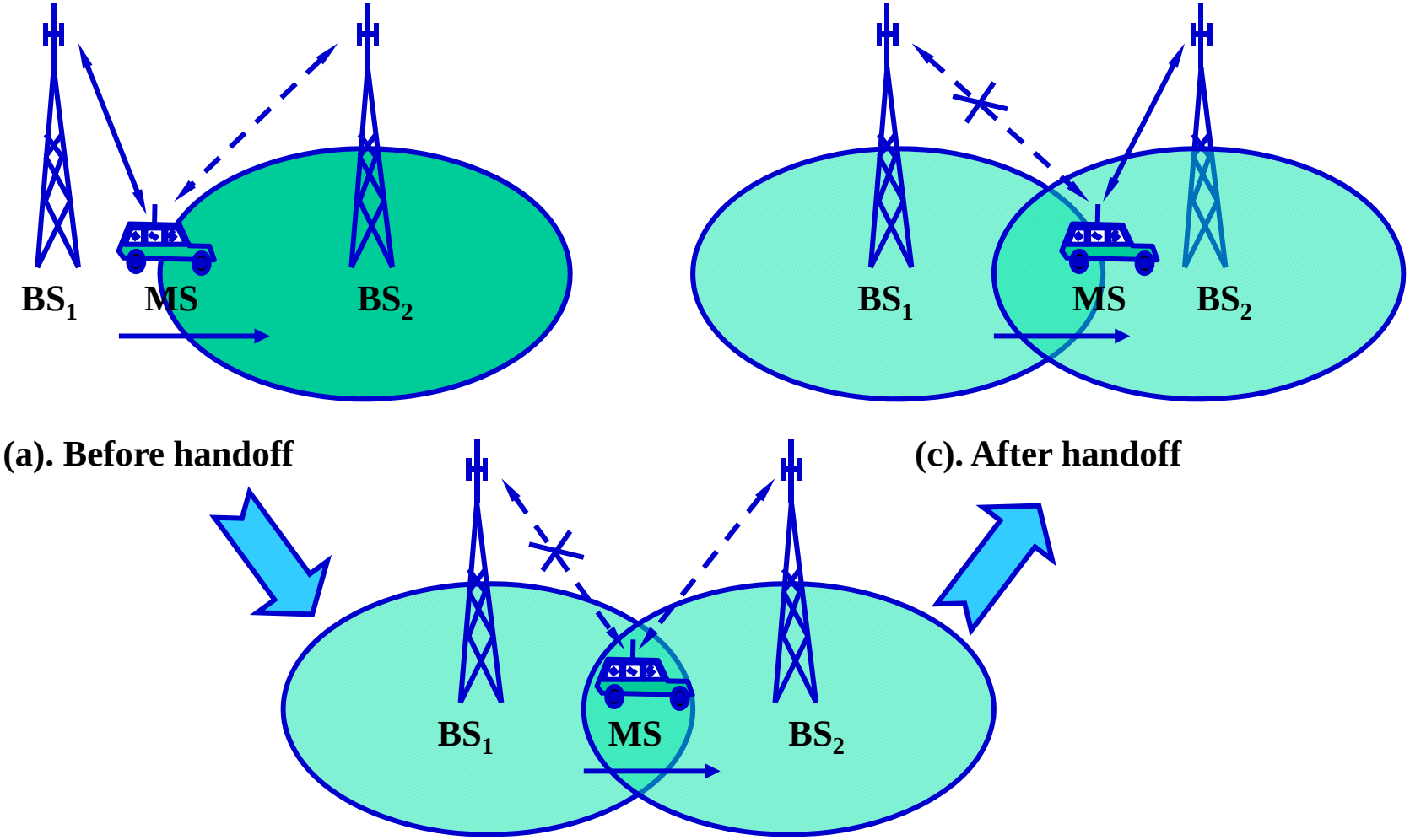
REGNOT – Registration notification messages:
QUALREQ – Qualification request message:
REGCANC – Registration cancellation message
PROFREQ – Service profile request message

Upper case represents ROSE INVOKE message
Lower case represents ROSE RETURN RESULTS message

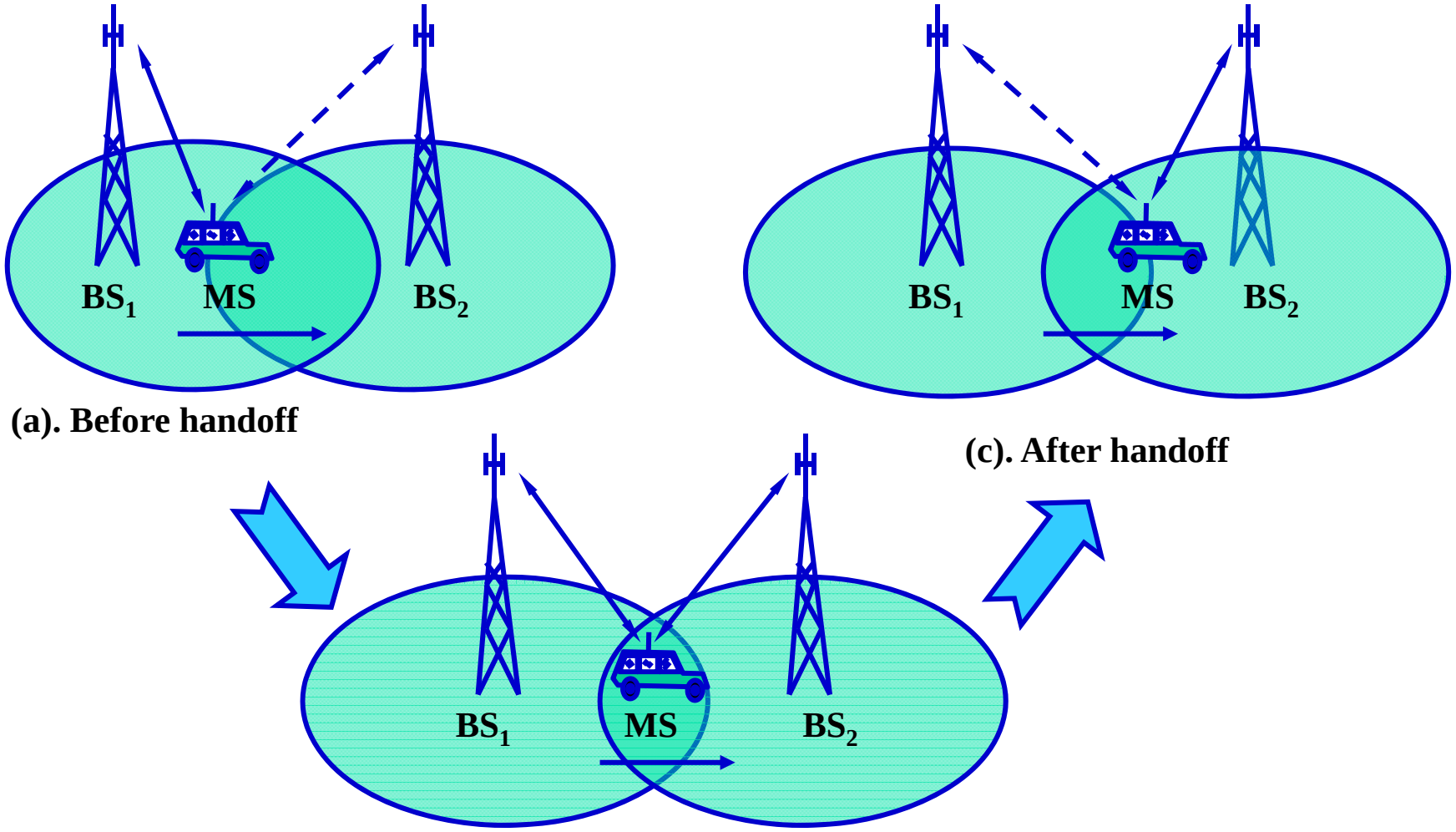
Types of Handoff

- Hard Handoff (*break before make*)
  - Releasing current resources from the prior BS before acquiring resources from the next BS
  - FDMA,TDMA follow this type of handoff
- Soft Handoff (*make before break*)
  - In CDMA, since the same channel is used, we can use the same if orthogonal to the codes in the next BS
  - Therefore, it is possible for the MS to communicate simultaneously with the prior BS as well as the new BS

Hard Handoff



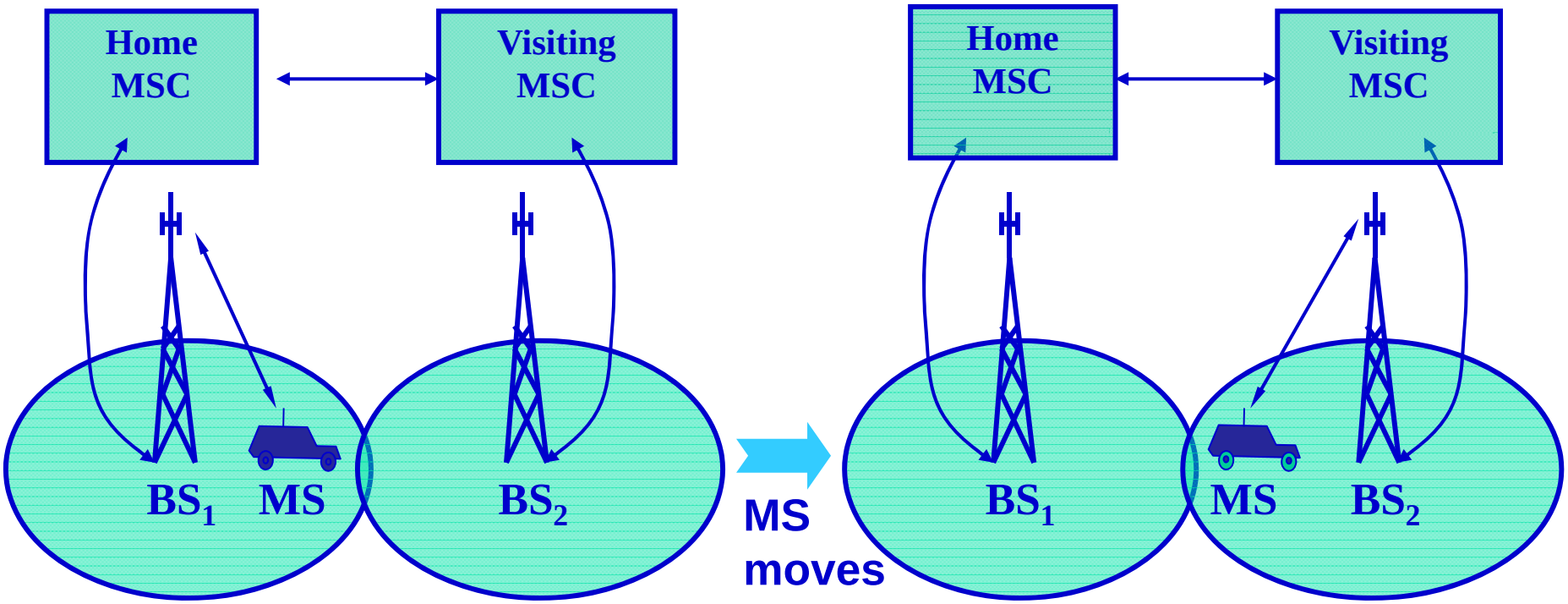
Soft Handoff (CDMA only)



Roaming Support

- To move from a cell controlled by one MSC area to a cell connected to another MSC
- Beacon signals and the use of HLR-VLR allow the MS to roam anywhere provided the same service provider using that particular frequency band, is there in that region

Roaming Support



Homework #4:

1. What's the architecture of the GSM system (including radio subsystem, network and switching subsystem, and fixed partner networks) ?
2. What's the mobile terminated call in the GSM system ?
3. What's the mobile originated call in the GSM system ?
4. What's handover procedure in the GSM system ?